Effects of Sound on the Marine Environment

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LONG-TERM GOALS

The long-term goals are to develop novel techniques to measure and predict, through modeling, the effect of sound on the marine environment. Modeling includes acoustic sources, propagation and the interaction of sound with animal behavior models. Determining the necessary environmental information such as bathymetry, sound speed and seabed properties for accurate modeling is also an essential component of this work.

OBJECTIVES

The objective of this research is to develop modeling tools for estimating the impact of sound on marine life. The goal is to provide state-of-the-art, open source codes to model sound sources, sound propagation and animal behavior. We are also assembling open source environmental databases for quantities such as seabed properties, bathymetry and ocean sound speed. Together, these tools will provide the best estimate of the impact of various sonar systems on the marine environment. These tools are bundled with a simple user interface in the One Navy Model (ONM) for Acoustic Effects Software (formerly known as the Effect of Sound on the Marine Environment (ESME) Workbench) which is intended to be a type of gold standard for estimating the impact of anthropogenic sound on marine mammals. Currently, Navy environmental impact statements are prepared at the Naval Undersea Warfare Center (NUWC) and by several government contractors. The software and databases being used are often either classified or proprietary. ONR has put together a team consisting Boston University (David Mountain), Biomimetica (Dorian Houser), HLS Research (Michael Porter) and Portland State University (Martin Siderius) to build the ESME Workbench, which will make the needed calculations for assessing environmental impact without using classified or proprietary components. In 2011 there were two main areas of work, 1) Creating a User Guide for the One Navy Model for Acoustic Effects Software. 2) Developing a simplified modeling capability to more quickly assess marine mammal harassments in large volumes of ocean.

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APPROACH

Approach to the User Guide for the One Navy Model for Acoustic Effects Software

The ONM software will be used by a variety of scientists and engineers to estimate the potential impact of anthropogenic sound on marine mammals. The software uses large environmental databases and a number of external programs to define sound sources and simulated animal (animat) populations (Houser, 2006). Sophisticated underwater acoustic propagation models are used to calculate sound field throughout the simulation environment, which are then used to estimate the number of animats that would be exposed to high sound levels. The ONM Software User Guide provides a structured overview of the various components of the program and a detailed explanation of the graphical user interface. It explains the features and functionality of the program so that users can quickly and easily learn how to install and run the software.

The ONM User Guide provides instructions to install the program and all of the necessary supplemental files on the local hard drive. Figure 1 shows a screen capture of the main Graphical User Interface (GUI) for the ONM software when the program is started.

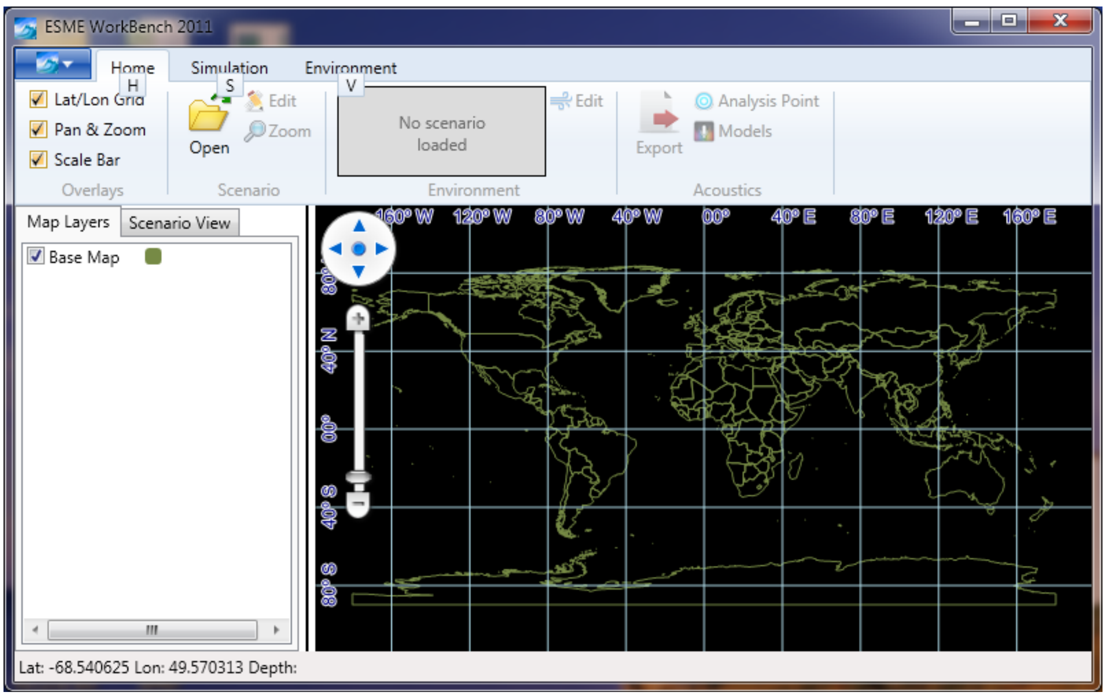

Figure 1. Graphical User Interface for the One Navy Model

Approach to a Simplified Modeling Capability

Often, underwater sound activity includes a number of sources at different frequencies possibly moving on different platforms (e.g. ships) for several hours or days. Calculating the expected sound pressure levels for these types of scenarios creates a significant computational burden. The size of the simulation space directly impacts the computation time for sophisticated propagation models to calculate sound exposure levels with high accuracy. A simpler propagation modeling approach could provide a means of quickly estimating the maximum extent (range) necessary to accurately assess marine mammal exposures due to anthropogenic activity.

Acoustic propagation modeling in the ocean is typically accomplished by calculating the transmission loss (TL) as a function of range and depth along a number of radials surrounding a sound source. For the ONM an underwater acoustics expert who is familiar with propagation effects in the local environment currently estimates the maximum range for the radials. If the radials do not extend far enough to include significant sound levels at distant ranges, then the potential for sound exposure to animals may be underestimated. This may lead modelers to overestimate the size of the simulation space. However, this requires the detailed propagation models (currently used in the ONM software) to load large input files and run sophisticated algorithms to compute sound levels at every point in the simulation space. Running such simulations in areas where there is negligible risk of acoustic exposure wastes valuable computation time and resources.

Simpler propagation models are being tested for use as a quicker tool to bridge the gap between human intuition and detailed propagation models. The development of a model combining simple predictions of transmission loss could provide a way to quickly estimate of the sound levels throughout large ocean volumes. Since these simple models are based on empirical or semi-empirical equations with a small number of inputs they would be relatively easy to program and implement into the existing framework of the ONM software. Thus, the resulting sound levels (as a function of depth, range and bearing) can then be associated with locations of simulated animals (animats) distributed in the simulation space within a Monte Carlo analysis. Therefore, this algorithm could estimate animat exposures as a function of range; providing a method to scientifically quantify the amount of error that would result in truncating the simulation area at any given range. This maximum range could then be used in a subsequent analysis that employs the more powerful propagation models already available in the ONM software. Finally, a comparison of the number of estimated exposures from both the simple and rigorous models could provide a means of validating and optimizing the simpler model.

WORK COMPLETED

Work completed on the User Guide for the One Navy Model for Acoustic Effects Software

Several drafts of the ONM Software User Guide have been developed in parallel with software releases to document the most recent features of the program. Two versions of the ONM have been developed. A classified version will use acoustic propagation models that are not available for public use outside the U.S. Navy. An unclassified version using open-source propagation models will be available for scientific research and investigation. Both versions of the software will use programs from the Naval Undersea Warfare Center (NUWC) to define acoustic sources and relate the sound levels to animat locations for acoustic exposure calculations and reporting. Engineers at NUWC are writing portions of the ONM User Guide to describe the functionality of their tools, while Portland State University is documenting the tools developed at Boston University.

Work Completed on a Simplified Modeling Capability

A literature review of some simple underwater acoustic propagation models has revealed a number of analytic models that can quickly calculate sound levels as function of range with a relatively small number of input variables. Models exist for propagation in the deep ocean as well as within surface ducts, which are bounded by reflection from the sea surface above and refraction from the deep ocean below. High intensity sound can travel great distances inside these relatively narrow channels and research indicates that anthropogenic sound in or near surface ducts may be associated with recent marine mammals strandings (D'Spain, 2006). Since maximum propagation typically occurs in ducts near the ocean surface, an analytic model could be used to calculate the distance at which sound pressure levels decrease to some predetermined level, (typically 120 dB, re: 1 μPa).

A quick evaluation of the sound speed profile (SSP) can provide an indication of whether or not there will be a surface duct. The thickness of the duct can also be estimated from the SSP. Then simple analytic models can be used to estimate the sound levels inside and below the surface duct. The sound speed profile (SSP) depends on a number of environmental and seasonal factors and is available to acoustic modelers through the databases in the ONM software.

The accuracy of these models can be evaluated against more rigorous propagation models, by comparing the number of animats that would be taken by the sound fields from each model. Matlab code has been written to associate sound fields with randomized animat locations in Monte Carlo simulations. The code can compare sound exposure levels for the animats against auditory thresholds to calculate the number of exposures that would occur with any given propagation model.

RESULTS

Results on the User Guide for the One Navy Model for Acoustic Effects Software

The ONM User Guide consists of 10 chapters. Each chapter opens with a brief purpose statement to outline main topics to be addressed. The manual then walks the user through the instructions to navigate the screens and menu options in a logical order. Figures created from screen captures of the GUI show the user what to expect during each step of the software installation and setup. A Table of Contents, List of Figures and Index allow the user to quickly navigate to any desired section of the document. The chapters' titles of the ONM User Guide are listed in Table 1.

Table 1. Chapters of the ONM User Guide

Chapter	Title
1	Overview
2	Getting Started
3	The User Interface
4	Environment Builder
5	Scenario Builder
6	Acoustic Builder
7	Animat Populator
8	Scenario Simulator
9	Post Processor
10	Report Generator

The Oceanographic and Atmospheric Master Library (OAML) databases contain bathymetry and sediment data for vast regions of the ocean, so that users may define scenarios to run almost anywhere in the world. The databases also include environmental data, which varies both geographically and seasonally, with records organized by month. In general, acoustic simulations will cover only a few hours or days with the maximum extent of acoustic propagation typically limited to a few hundred kilometers from the source location. Thus, only a relatively small sub-set of the total OAML data is required to run a given simulation.

Figure 3 shows a screen capture from the ONM Software after bathymetry data has been extracted and loaded for a range complex off the coast of Florida. Bathymetry data for shallow to deep-ocean is displayed in colors ranging from red to blue, respectively. Land is shown in dark green. An analysis point defines a source location that is surrounded by 16 radials extending to the maximum range of the simulation space. Propagation models compute the sound levels for all ranges and depths along each of the radials.

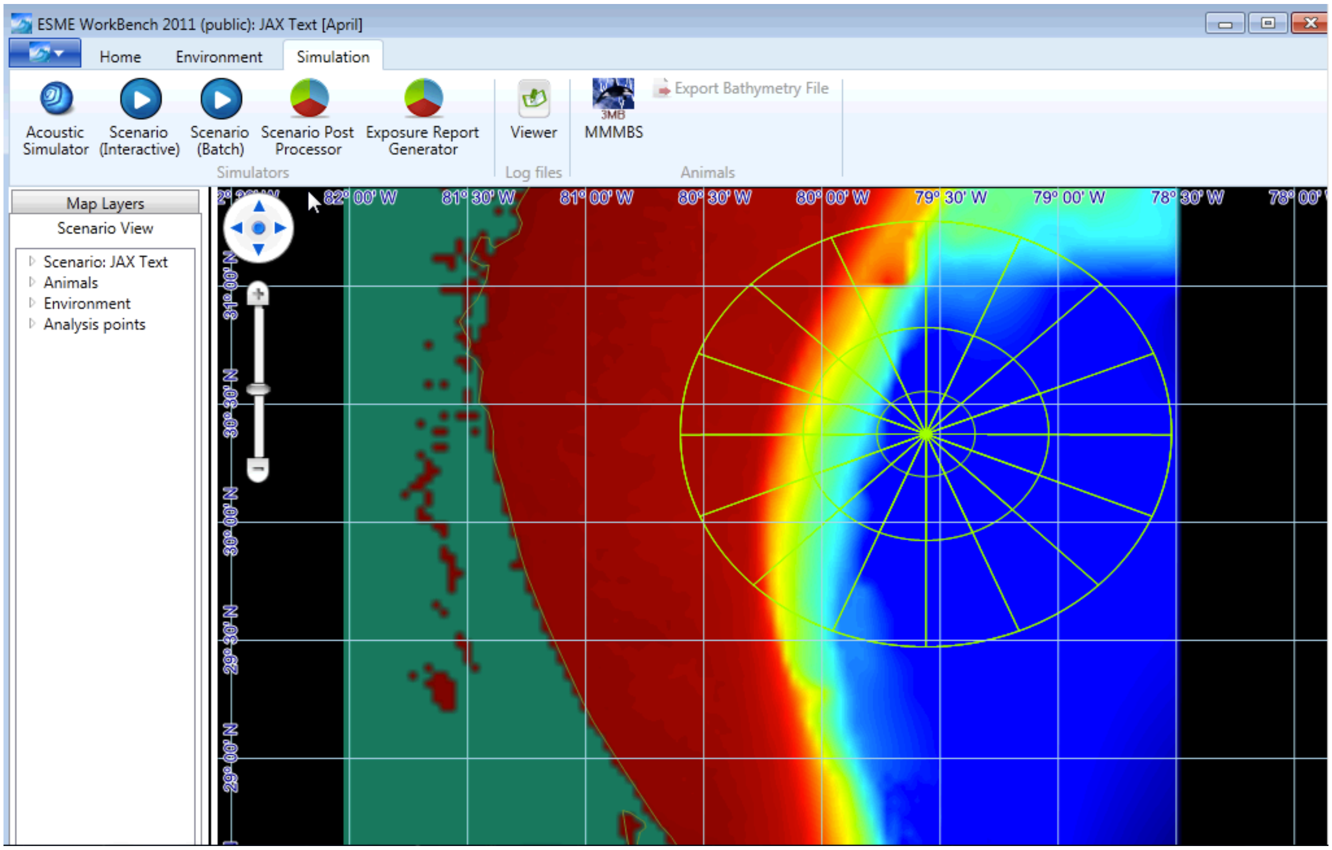

Figure 3. ONM Screen capture for a range complex off the coast of Florida.

IMPACT/APPLICATIONS

The ONM Software user guide provides a structured overview of the various components of the program and a detailed explanation of the graphical user interface. It will enable scientists and engineers to install the software and supplemental databases and programs, and to quickly learn how to set up simulation environments and process results. In addition, a simpler and faster propagation model could provide a systematic and logical method for estimating the maximum range at which marine mammals could be affected by manmade sound in the ocean. Such a model would fill a gap between human intuition and more rigorous computer models; making marine mammal exposure calculations faster and more accurate. Since these models are simple to program, they could be easily implemented into the existing framework of the ONM software.

TRANSITIONS

None at this time.

RELATED PROJECTS

None at this time.

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